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APPLICATION FOR  
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SPECIFICATION

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**DESCRIPTION**

**NOISE REMOVING CIRCUIT**

**5 Technical Field**

The present invention relates to a noise removing circuit removing a noise component included in a signal in a receiver, etc.

**10 Background Art**

Noise caused by another car-mounted appliance is apt to be mixed into a signal input/output to/from an AM or FM receiver mounted in a car. Accordingly, various types of noise removing circuits are conventionally adopted. As one of examples, there is a method removing noise by extracting a noise component from a signal, by masking part of the signal, which corresponds to the noise component, and by holding the voltage of the immediately preceding input signal. With this method, a pulse signal is generated to mask the noise. However, if attempts are made to mask the noise, timing when the noise occurs and timing when the pulse signal generated based on this noise occurs must be made to match. Since a predetermined amount of time is naturally required to generate the pulse signal, an analog delaying circuit

delaying the signal from which the noise is to be removed by the predetermined amount of time becomes necessary. Conventionally, a plurality of stages (such as 4 stages) of Bessel type filters are used as this analog delaying 5 circuit.

In the meantime, since the above described Bessel type filters are configured by combining a resistor, a capacitor, and an operational amplifier, the whole of the analog delaying circuit, namely, the whole of 10 the noise removing circuit cannot be formed on a semiconductor substrate if the device constants of the resistor and the capacitor are considered. Especially, even if a resistor and a capacitor, which have a large device constant, are formed on a semiconductor substrate, 15 variations in the device constants of the resistor, etc. formed on the semiconductor substrate are large. Therefore, the delay time of the analog delaying circuit significantly varies. If attempts are made to precisely remove only noise, the delay time of the analog delaying 20 circuit must be set with high accuracy. It is difficult for the analog delaying circuit using the Bessel type filters, which is formed on the semiconductor substrate, to satisfy this accuracy requirement.

25 **Disclosure of Invention**

The present invention is devised in view of such a point, and an object thereof is to provide a noise removing circuit that can be integrally formed on a semiconductor substrate, and can improve the accuracy 5 of noise component removal.

To overcome the above described problem, the noise removing circuit according to the present invention comprises: a highpass filter detecting a noise component included in an input signal; a pulse generating circuit 10 generating a pulse having a predetermined width at timing when the voltage level of the noise component output from the highpass filter becomes equal to or higher than a predetermined reference voltage; an analog delaying circuit delaying the input signal by a 15 predetermined amount of time, and outputting the delayed signal; and an outputting circuit holding the signal output from the analog delaying circuit at immediately preceding timing when the pulse generated by the pulse generating circuit is input, and outputting the signal 20 output from the analog delaying circuit unchanged in other cases. Additionally, the analog delaying circuit comprises: a plurality of capacitors; a plurality of first switches making the plurality of capacitors respectively hold the voltage of the input signal, which 25 corresponds to supply timing, by supplying the input

signal to the plurality of capacitors in a predetermined order at the different timing; and a plurality of second switches extracting the voltage of the input signal respectively held by the plurality of capacitors before 5 the next timing when the voltage is held is reached. As described above, the plurality of first switches within the analog delaying circuit are made electrically continuous in a sequential order, the voltage of the input signal at each time point is held in each of the 10 plurality of capacitors, and the plurality of second switches are made electrically continuous and the held voltage is extracted before being updated, whereby the output timing of the signal can be delayed by the amount of time required from when the first switches are made 15 electrically continuous until when the second switches are made electrically continuous. Especially, the analog delaying circuit is configured by using the first and the second switches the disconnection states of which can be switched, and the capacitors each holding 20 the voltage of the signal. This eliminates the need for using a resistor and a capacitor, which have a large device constant. As a result, the whole of the noise removing circuit including the analog delaying circuit can be easily formed on a semiconductor substrate. 25 Additionally, the amount of time required from when the

first switches are made electrically continuous until when the second switches are made electrically continuous becomes the delay time of the signal. Therefore, the delay time can be set regardless of 5 variations in device constants, so that the timing when the pulse is generated by the pulse generating circuit, and the delay time implemented by the analog delaying circuit can be made to precisely match. As a result, the accuracy of noise component removal can be improved.

10 Another noise removing circuit according to the present invention comprises: a noise extracting circuit extracting a noise component included in an input signal; a pulse generating circuit generating a pulse having a predetermined width at timing when the voltage 15 level of the noise component output from the noise extracting circuit becomes a predetermined reference voltage or higher; an analog delaying circuit having a plurality of capacitors, a plurality of first switches making the plurality of capacitors respectively hold 20 the voltage of the input signal in correspondence with supply timing by respectively supplying the input signal to the plurality of capacitors in a predetermined order at different timing, and a plurality of second switches making the plurality of capacitors output the voltage 25 of the input signal respectively held by the plurality

of capacitors in a predetermined order at timing delayed by a predetermined amount of time required until when the pulse having the predetermined width is output from the pulse generating circuit; and an outputting circuit 5 holding the signal output from the analog delaying circuit at immediately preceding timing when the pulse having the predetermined width is output from the pulse generating circuit, and outputting the signal output from the analog delaying circuit unchanged in other 10 cases.

According to the present invention, the amount of time required from when the first switches are made electrically continuous until when the second switches are made electrically continuous becomes the delay time 15 of an input signal, whereby the delay time can be set regardless of variations in device constants. As a result, the amount of time required from when noise is detected until when the pulse generating circuit generates a pulse having a predetermined width, and the 20 delay time implemented by the analog delaying circuit can be made to precisely match with ease, whereby the accuracy of noise component removal can be improved. Additionally, the analog delaying circuit is configured by the pluralities of first and second switches, and 25 the plurality of capacitors, whereby the analog delaying

circuit can be implemented without using a resistor and a capacitor, which have a large device constant. As a result, for example, the whole of the noise removing circuit including the analog delaying circuit can be 5 easily formed on a semiconductor substrate.

Additionally, it is desirable to connect the output terminals of the above described plurality of second switches in common. As a result, the voltage of the signal, which is respectively distributed to and 10 held by the plurality of capacitors, can be output as a sequential signal from the analog delaying circuit.

Furthermore, it is desirable to exclusively make the above described plurality of first switches electrically continuous. Or, it is desirable to 15 exclusively make the above described plurality of second switches electrically continuous. As a result, charge and discharge operations of each of the plurality of capacitors within the analog delaying circuit can be separately performed, so that the charge and discharge 20 operations of each of the capacitors can be stabilized.

Still further, it is desirable that each of the above described pluralities of first and second switches is an analog switch configured by connecting an FET of a p-channel type and an FET of an n-channel type in 25 parallel. As a result, a resistance value when the first

and the second switches are made electrically continuous can be made almost constant regardless of the voltage of an input signal, so that the distortion of the output signal of the analog delaying circuit due to a change 5 in the voltage of the input signal can be prevented from occurring.

Still further, it is desirable that the above described analog delaying circuit further comprises clock generating means for generating a clock signal 10 that cyclically selects the pluralities of first and second switches. Each disconnection timing of the pluralities of first and second switches can be controlled by generating the clock signal, whereby the need for a complex control mechanism is eliminated, and 15 the circuit configuration can be simplified.

Still further, it is desirable that the above described analog delaying circuit further comprises an output capacitor connected to the plurality of capacitors via the plurality of second switches. As a 20 result, even if the output signal is intermittently extracted from the plurality of capacitors, a sudden variation in the voltage of the output signal can be suppressed.

Still further, it is desirable to set the 25 capacitance of the above described output capacitor to

a value smaller than the respective capacitances of the plurality of capacitors. As a result, the output signal, which varies with the voltage held by the plurality of capacitors, can be extracted with ease.

5 Still further, it is desirable that the respective constituent elements can be integrally formed on a semiconductor substrate. By using the above described analog delaying circuit, the whole of the noise removing circuit can be formed integrally. This can reduce the  
10 whole of the circuit in size and cost.

Besides, the clock generating means supplies the clock signal, whose one cycle is the amount of time required until when the pulse having the predetermined width is output from the pulse generating circuit, to  
15 the first and the second switches in a sequential order.

#### **Brief Description of Drawings**

Fig. 1 shows a partial configuration of an FM receiver including a noise removing circuit according  
20 to one preferred embodiment;

Fig. 2 shows the configuration of the noise removing circuit shown in Fig. 1;

Fig. 3 is a timing diagram showing the operation state of the noise removing circuit according to the  
25 preferred embodiment;

Fig. 4 is a circuit block diagram showing a time constant circuit;

Fig. 5 is a circuit diagram showing a specific configuration of the time constant circuit;

5 Fig. 6 shows the details of the configuration of an analog delaying circuit; and

Fig. 7 shows the operation timing of the analog delaying circuit.

#### 10 **Best Mode for Carrying Out the Invention**

Hereinafter, a noise removing circuit according to one preferred embodiment, to which the present invention is applied, is described with reference to the drawings.

15 Fig. 1 shows a partial configuration of an FM receiver including a noise removing circuit according to one preferred embodiment. As shown in Fig. 1, the FM receiver in this preferred embodiment is configured by comprising an FM detecting circuit 10, a noise removing circuit 30, and a stereo demodulating circuit 60. The FM detecting circuit 10 outputs a stereo composite signal by executing an FM detection process for an intermediate frequency signal amplified by an intermediate frequency amplifying circuit (not shown).  
20 The noise removing circuit 30 removes noise included  
25 The noise removing circuit 30 removes noise included

in the FM stereo composite signal input from the FM detecting circuit 10. The stereo demodulating circuit 60 executes a stereo demodulation process for separating L and R signals included in the input stereo composite 5 signal.

Fig. 2 shows the configuration of the noise removing circuit 30 shown in Fig. 1. As shown in Fig. 2, the noise removing circuit 30 is configured by comprising a highpass filter (HPF) 232, an amplifier 10 234, a full-wave rectifying circuit 236, a time constant circuit 100, a voltage comparator 240, a 1-shot circuit 242, an amplifier 250, an analog delaying circuit 252, an FET 254, a capacitor 256, and a buffer 258. In this preferred embodiment, the noise removing circuit 30 and 15 the whole of its peripheral circuits are integrally formed on a semiconductor substrate with a CMOS process, etc. depending on need.

The highpass filter (corresponding to a noise extracting circuit) 232 makes only a high-frequency 20 component, which includes a noise component included in the stereo composite signal output from the FM detecting circuit 10, pass through. The amplifier 234 amplifies the noise component that passes through the highpass filter 232 with a gain corresponding to an 25 applied control voltage. The full-wave rectifying

circuit 236 makes full-wave rectification for the amplified noise component output from the amplifier 234. Generally, noises mixed into a signal having a predetermined voltage level are noise having a negative 5 polarity in addition to that having a positive polarity. Therefore, the full-wave rectifying circuit 236 rectifies the two types of noise components having different polarities, and generates a noise component having the same polarity. The time constant circuit 100 10 generates a control voltage applied to the amplifier 234 by smoothing the noise component rectified by the full-wave rectifying circuit 236 with a predetermined time constant. Details of the configuration and the operations of the time constant circuit 100 will be 15 described later.

The voltage comparator 240 makes a comparison between the noise component rectified by the full-wave rectifying circuit 236 and a predetermined reference voltage  $V_{ref}$ , and makes the level of the output high 20 in correspondence with noise whose peak value exceeds the reference voltage  $V_{ref}$ . The 1-shot circuit 242 generates a one-shot pulse having a predetermined pulse width when the level of the output of the voltage comparator 240 becomes high, namely, when noise is 25 detected.

The amplifier 250 amplifies the stereo composite signal that is detected and output from the FM detecting circuit 10. The analog delaying circuit 252 delays the input stereo composite signal by a predetermined amount 5 of time, and outputs the delayed signal. This delay time is set in correspondence with the processing time of the respective circuits from the above described highpass filter 232 to the one-shot circuit 242. The FET 254 is a switching element that makes the stereo 10 composite signal output from the analog delaying circuit 252 pass through, or interrupts the signal. The FET 254 interrupts the stereo composite signal when the pulse output from the one-shot circuit 242 is input to a gate, or makes the signal pass through in other cases. The 15 capacitor 256 holds the immediately preceding level of the signal when the stereo composite signal is interrupted by the FET 254. The buffer 258 has high-input impedance. The stereo composite signal that passes through the FET 254, or the voltage held by the capacitor 20 256, which is immediately preceding the interrupt, is externally extracted via this buffer 258.

The above described voltage comparator 240 and one-shot circuit 242, and the FET 254, the capacitor 256, and the buffer 258 respectively correspond to the 25 pulse generating circuit, and the outputting circuit.

Fig. 3 is a timing diagram showing the operation state of the noise removing circuit 30 according to this preferred embodiment. In Fig. 3, (A) to (F) respectively show the input/output signal waveforms of the units 5 denoted with the same reference numerals as those in Fig. 2.

When the stereo composite signal in which noise is mixed is output from the FM detecting circuit 10 (Fig. 3(A)), the noise component included in the stereo 10 composite signal is extracted by the highpass filter 232 (Fig. 3(B)). The full-wave rectifying circuit 236 rectifies the noise component (Fig. 3(C)), and the one-shot circuit 242 generates a pulse signal corresponding to each noise (Fig. 3(D)).

15        Additionally, the analog delaying circuit 252 delays the stereo composite signal output from the FM detecting circuit 10 by the amount of time required to generate the pulse signal, and outputs the delayed signal (Fig. 3(E)). As a result, the timing when the 20 noise included in the stereo composite signal is output, and the timing when the pulse corresponding to the noise is output from the one-shot circuit 242 are made to match. The FET 254 interrupts the input stereo composite signal when the pulse is output from the one-shot circuit 242. 25        When the signal is interrupted, the voltage held by the

capacitor 256 immediately preceding the interrupt is extracted by the buffer 258. Therefore, the portion corresponding to the noise component is replaced with the immediately preceding voltage in the stereo composite signal output from the buffer 258.

In the meantime, the time constant of the time constant circuit 100 is set to a value to a degree not responding to random noise as shown in Fig. 3(C). However, especially, in the case of FM broadcasting, white noise tends to increase as a whole if the intensity of the reception electric field of the broadcasting wave decreases. In such a case, the control voltage generated by the time constant circuit 100 rises, and the gain of the amplifier 234 drops. Accordingly, the output voltage of the full-wave rectifying circuit 236 becomes low, and the output voltage of the voltage comparator 240 holds a low level, so that the one-shot circuit 242 does not generate the pulse. Accordingly, the stereo composite signal output from the analog delaying circuit 252 is output via the buffer 258 without being interrupted by the FET 254. If the white noise included in the stereo composite signal increases, the interrupt of the signal by the FET 254 must be immediately stopped. Therefore, the amount of time (attack time) during which the control voltage generated by the time constant

circuit 100 rises and the gain of the amplifier 234 drops must be set to a small value. In the meantime, it is desirable to set the amount of time (release time) during which the gain of the amplifier 234 rises to some large 5 value in consideration of the stability of the operations, etc.

Fig. 4 is a circuit block diagram showing the time constant circuit 100. As shown in Fig. 4, the time constant circuit 100 in this preferred embodiment 10 comprises a capacitor 110, a voltage comparator 112, a charge circuit 114, a discharge circuit 116, and a charge/discharge speed setting unit 118. The voltage comparator 112 makes a comparison between the terminal voltage of the capacitor 110 and the input voltage, and 15 validates the operations of the charge circuit 114 or the discharge circuit 116 according to a comparison result. The charge circuit 114 charges the capacitor 110 by intermittently supplying a charge current. For example, this charge circuit 114 is configured by 20 comprising a constant-current circuit and a switch. When the switch switches to an ON state, the charge current is supplied from the constant-current circuit to the capacitor 110. Additionally, the discharge circuit 116 discharges the capacitor 110 by intermittently 25 supplying a discharge current. For example, the

discharge circuit 116 is configured by comprising a constant-current circuit and a switch. When the switch switches to an ON state, the constant current is emitted from the capacitor 110. The charge/discharge speed 5 setting unit 118 makes settings such that the speed at which the capacitor 110 is charged by the charge circuit 114, and the speed at which the capacitor 110 is discharged by the discharge circuit 116 are made different.

10 As described above, the time constant circuit 100 in this preferred embodiment performs the intermittent charge/discharge operations for the capacitor 110. Accordingly, even if the capacitance of the capacitor 110 is set to a small value, the voltage of the capacitor 15 varies moderately, and a charge/discharge characteristic equivalent to that in the case where a circuit having a large time constant, namely, a capacitor having a large capacitance, or a resistor having a large resistance value is used can be obtained.

20 Additionally, the charge circuit 114 or the discharge circuit 116 performs control for supplying or emitting the predetermined current to/from the capacitor 110. Since these supply/emission operations are intermittently performed, the current value at that time 25 can be set to some large value, which is suitable for

being put into an IC. Accordingly, it becomes easy to form the noise removing circuit 30 including the time constant circuit 100 on a semiconductor substrate, and to put the circuits into an IC. Additionally, since 5 externally attached components such as a capacitor, etc. become unnecessary, the whole of the noise removing circuit 30 can be significantly reduced in size.

Furthermore, in the time constant circuit 100 in this preferred embodiment, settings such that the charge 10 and the discharge speeds for the capacitor 110 are made different are made by the charge/discharge speed setting unit 118. Accordingly, the amount of time during which the gain of the amplifier 234 drops with a rise in the control voltage, and the amount of time during which 15 the gain of the amplifier 234 rises with a drop in the control voltage can be made different.

Fig. 5 is a circuit diagram showing a specific configuration of the time constant circuit 100. As shown in Fig. 5, the time constant circuit 100 is configured 20 by comprising a capacitor 110, a constant-current circuit 140, FETs 142, 144, 150, 154, and 156, switches 146 and 152, a voltage comparator 160, AND circuits 162 and 164, and a frequency divider 170.

A current mirror circuit is configured by the two 25 FETs 142 and 144, and the same charge current as the

constant current output from the constant-current circuit 140 is generated. Additionally, the generation timing of the charge current is determined by the switch 146.

5        The switch 146 is configured by an inverter circuit 1, an analog switch 2, and an FET 3. The analog switch 2 is configured by connecting the sources and the drains of a p-channel FET and an n-channel FET in parallel. The output signal of the AND circuit 162 is  
10      directly input to the gate of the n-channel FET, and at the same time, a signal obtained by inverting the logic of this output signal with the inverter circuit 1 is input to the gate of the p-channel FET. Accordingly, the analog switch 2 switches to an ON state when the output  
15      signal of the AND circuit 162 is a high level, or switches to an OFF state when the output signal of the AND circuit 162 is a low level. Additionally, the FET 3 is intended to securely stop the current supply operation performed by the FET 144 by connecting between the gate and the  
20      drain of the FET 144 with low resistance when the analog switch 2 is in an OFF state.

When the switch 146 switches to an ON state, the gate of one FET 142, to which the constant-current circuit 140 is connected, and the gate of the other FET  
25      144 becomes a connection state. Therefore, a current

almost the same as the constant current, which is generated by the constant current circuit 140 connected to one FET 142, also flows between the source and the drain of the other FET 144. This current is supplied 5 to the capacitor 110 as a charge current. Or, if the switch 146 switches to an OFF state, the gate of the FET 144 becomes a state of being connected to the drain. Therefore, this charge current supply is stopped.

Furthermore, a current mirror circuit, which sets 10 the discharge current of the capacitor 110, is configured by combining the FET 150 with the above described FET 142 and constant-current circuit 140, and its operation state is determined by the switch 152. The switch 152 has the same configuration as that of 15 the switch 146. The ON/OFF state of this switch 152 is controlled according to the logic of the output signal of the AND circuit 164. The switch 152 switches to an ON state when the output signal is a high level, or switches to an OFF state when the output signal is a 20 low level.

When the switch 152 switches to the ON state, the gate of one FET 142 to which the constant-current circuit 140 is connected, and the gate of the other FET 150 switches to the connection state. Therefore, almost the 25 same current as the constant current generated by the

constant current circuit 140 also flows between the source and the drain of the other FET 150. This current becomes the discharge current that emits an electric charge accumulated in the capacitor 110.

5        However, the current flowing into the FET 150 cannot be directly extracted from the capacitor 110. Therefore, another current mirror circuit configured by the FETs 154 and 156 is connected to the source side of the FET 150 in this preferred embodiment.

10       The gates of the two FETs 154 and 156 are connected, so that the same current also flows between the source and the drain of the other FET 156 when the above described discharge current flows into the FET 154. The drain of this FET 156 is connected to a terminal on the 15 high potential side of the capacitor 110. The current flowing into the FET 156 is generated in a way such that the electric charge accumulated in the capacitor 110 is emitted.

20       Additionally, the voltage comparator 160 makes a comparison of whether the terminal voltage of the capacitor 110, which is applied to a plus terminal, is either higher or lower than the input voltage of the time constant circuit 100, which is applied to a minus terminal. This voltage comparator 160 comprises a 25 non-inversion output terminal and an inversion output

terminal. If the terminal voltage of the capacitor 110, which is applied to the plus terminal, is higher than the input voltage, which is applied to the minus terminal, a high-level signal is output from the non-inversion output terminal, and a low-level signal is output from the inversion output terminal. Or, if the terminal voltage of the capacitor 110, which is applied to the plus terminal, is lower than the input voltage, which is applied to the minus terminal, a low-level signal is output from the non-inversion output terminal, and a high-level signal is output from the inversion output terminal.

For the AND circuit 162, a predetermined pulse signal is input to one of its input terminals, and the non-inversion output terminal of the voltage comparator 160 is connected to the other of the input terminals. Accordingly, a predetermined pulse signal is output from the AND circuit 162 if the terminal voltage of the capacitor 110 is higher than the input voltage of the time constant circuit 100.

Additionally, for the AND circuit 164, a predetermined pulse signal output from the frequency divider 170 is input to one of its input terminals, and the inversion output terminal of the voltage comparator 160 is connected to the other of the input terminals.

Accordingly, a predetermined pulse signal is output from the AND circuit 164 if the terminal voltage of the capacitor 110 is lower than the input voltage of the time constant circuit 100.

5        The frequency divider 170 divides the pulse signal input to one of the input terminals of the AND circuit 162 at a predetermined frequency division ratio, and outputs the divided signal. As described above, the pulse signal after being frequency-divided is input to  
10      one of the input terminals of the AND circuit 164.

      The time constant circuit 100 has such a configuration, and its operations are described next.

      If the capacitor 110 is not charged when the operations of the time constant circuit 100 start, or  
15      if the input voltage of the time constant circuit 100 tends to rise, the terminal voltage of the capacitor 110 is in a state of being lower than the input voltage of the time constant circuit 100. At this time, the pulse signal is output from the AND circuit 162, whereas the  
20      pulse signal is not output from the AND circuit 164.

      Accordingly, only the switch 146 intermittently switches to the ON state, and a predetermined charge current is supplied to the capacitor 110 at the timing when the switch 146 switches to the ON state. This charge  
25      operation is continued until when the terminal voltage

of the capacitor 110 becomes relatively higher than the input voltage of the time constant circuit 100.

Or, if the terminal voltage of the capacitor 110 exceeds the input voltage of the time constant circuit 100 with this charge operation, or if the input voltage tends to drop, and the input voltage is lower than the terminal voltage of the capacitor 110, the pulse signal is output from the AND circuit 164, but the pulse signal is not output from the AND circuit 162. Accordingly, 10 only the switch 152 intermittently switches to an ON state, and a predetermined discharge current is emitted from the capacitor 110 when the switch 152 switches to the ON state. This discharge operation is continued until when the terminal voltage of the capacitor 110 15 becomes relatively lower than the input voltage of the time constant circuit 100.

Making a comparison between the two types of the pulse signals output from the above described two AND circuits 162 and 164, the duty ratio of the pulse signal 20 output from the AND circuit 162 is higher than that of the pulse signal output from the AND circuit 164. Therefore, the charge speed per unit time is faster than the discharge speed per unit time if a case where the pulse signals are output respectively from the two AND 25 circuits 162 and 164 for the same time period is

considered.

In the above described time constant circuit 100, the frequency divider 170 is used to output the pulse signals having the different duty ratios from the two 5 AND circuits 162 and 164. However, pulse signals having different duty ratios may be separately generated, and respectively input to the two AND circuits 162 and 164. Or, the charge time and the discharge time of the capacitor 100 can be made identical by removing the 10 frequency divider 170.

Additionally, the ratios of the ON states of the FETs 144 and 150 per unit time are made different in order to make the charge speed and the discharge speed for the capacitor 100 differ in the above described time 15 constant circuit 100. However, the sizes of the gates of these FETs are made different, so that the charge and the discharge currents themselves may be made different.

Fig. 6 shows the details of the configuration of 20 the analog delaying circuit 252. As shown in Fig. 6, the analog delaying circuit 252 is configured by comprising a clock generating unit 50, analog switches 51 to 56 and 61 to 66, inverter circuits 71 to 76, and capacitors 81 to 86 and 90. The above described analog 25 switches 51 to 56, and analog switches 61 to 66

respectively correspond to the first and the second switches.

The clock generating unit 50 generates 6 clock signals CLK1 to 6 having different output timing in a predetermined order. For these 6 clock signals CLK1 to 6, their cycles are the same, and their high-level durations are set to be mutually exclusive and redundant. Additionally, the cycles of the clock signals CLK1 to 6 are set to match with the amount of time required from when noise is detected until when the pulse is output from the one-shot circuit 242. This clock generating unit 50 corresponds to the clock generating means.

The first clock signal CLK1 is input to the two analog switches 51 and 62 directly and via the inverter circuit 71. If one analog switch 51 becomes electrically continuous in correspondence with the clock signal CLK1, the voltage of the input signal at this electrical continuity timing is applied to the capacitor 81, and the applied voltage is held by the capacitor 81. Or, if the other analog switch 62 becomes electrically continuous in correspondence with the clock signal CLK1, one end of the capacitor 82 is connected to the output terminal side, and the voltage held by the capacitor 82 is externally extracted as an output voltage.

The second clock signal CLK2 is input to the two

analog switches 52 and 63 directly and via the inverter circuit 72. If one analog switch 52 becomes electrically continuous in correspondence with the clock signal CLK2, the voltage of the input signal at this electrical 5 continuity timing is applied to the capacitor 82, and this applied voltage is held by the capacitor 82. Or, if the other analog switch 63 becomes electrically continuous in correspondence with the clock signal CLK2, one end of the capacitor 83 is connected to the output 10 terminal side, and the voltage held by the capacitor 83 is externally extracted as an output voltage.

The third clock signal CLK3 is input to the two analog switches 53 and 64 directly and via the inverter circuit 73. If one analog switch 53 becomes electrically 15 continuous in correspondence with the clock signal CLK3, the voltage of the input signal at this electrical continuity timing is applied to the capacitor 83, and the applied voltage is held by the capacitor 83. Or, if the other analog switch 64 becomes electrically 20 continuous in correspondence with the clock signal CLK3, one end of the capacitor 84 is connected to the output terminal side, and the voltage held by the capacitor 84 is externally extracted as an output voltage.

The fourth clock signal CLK4 is input to the two 25 analog switches 54 and 65 directly and via the inverter

circuit 74. If one analog switch 54 becomes electrically continuous in correspondence with the clock signal CLK4, the voltage of the input signal at this electrical continuity timing is applied to the capacitor 84, and 5 the applied voltage is held by the capacitor 84. Or, if the other analog switch 65 becomes electrically continuous in correspondence with the clock signal CLK4, one end of the capacitor 85 is connected to the output terminal side, and the voltage held by the capacitor 10 85 is externally extracted as an output voltage.

The fifth clock signal CLK5 is input to the two analog switches 55 and 66 directly and via the inverter circuit 75. If one analog switch 55 becomes electrically continuous in correspondence with the clock signal CLK5, 15 the voltage of the input signal at this electrical continuity timing is applied to the capacitor 85, and the applied voltage is held by the capacitor 85. Or, if the other analog switch 66 becomes electrically continuous in correspondence with the clock signal CLK5, 20 one end of the capacitor 86 is connected to the output terminal side, and the voltage held by the capacitor 86 is externally extracted as an output voltage.

The sixth clock signal CLK6 is input to the two analog switches 56 and 61 directly and via the inverter 25 circuit 76. If one analog switch 56 becomes electrically

continuous in correspondence with the clock signal CLK6, the voltage of the input signal at this electrical continuity timing is applied to the capacitor 86, and the applied voltage is held by the capacitor 86. Or, 5 if the other analog switch 61 becomes electrically continuous in correspondence with the clock signal CLK6, one end of the capacitor 81 is connected to the output terminal side, and the voltage held by the capacitor 81 is externally extracted as an output voltage.

10 The capacitor 90 is an output capacitor for smoothing. If all of the analog switches 61 to 66 are in a non-continuity state, the voltages which are held by the capacitors 81 to 86 and extracted on the output terminal side immediately preceding the non-continuity 15 state, are maintained. The capacitance of this capacitor 90 is set to a value smaller than the respective capacitances of the other capacitors 81 to 86, such as approximately 1/10. As a result, it becomes easy to generate an output signal that varies with the voltages 20 respectively held by the capacitors 81 to 86, and to extract the signal externally to the analog delaying circuit 252.

Additionally, each of the above described analog switches 51 to 56 and 61 to 66 is configured by connecting 25 an FET of a p-channel type and an FET of an n-channel

type in parallel. Accordingly, ON resistance becomes almost constant even if the voltage level of an input signal varies, so that the distortion of an output signal does not occur when the voltage level of the input signal 5 varies.

Next, the operations of the analog delaying circuit 252 in this preferred embodiment are described.

Fig. 7 shows the operation timing of the analog delaying circuit 252. In Fig. 7, numerals 1 to 12 10 respectively assigned to the clock signals CLK1 to 6 show the output order (order where the clock signals exclusively become a high level) of the clock signals. Thus, the 6 types of clock signals CLK1 to CLK6, which 15 cyclically select the analog switches 51 to 56 and 61 to 66, are output from the clock generating unit 50. In this preferred embodiment, "redundant selection" means that the 6 analog switches are sequentially selected, and the sequential selection restarts from the first switch after completing the selection once.

20 When the clock signal CLK1 is initially input (number 1), the analog switch 51 becomes electrically continuous at this timing, and the capacitor 81 is charged, so that the voltage of the input signal is held. Similarly, when the clock signal CLK2 is input next 25 (number 2), the analog switch 52 becomes electrically

continuous at this timing, and the capacitor 82 is charged, so that the voltage of the input signal is held.

As described above, when the clock signals CLK1 to 6 are sequentially input, the respectively 5 corresponding analog switches 51 to 56 become electrically continuous, and the voltage of the input signal is held in the capacitors connected in the later stage.

Furthermore, the voltages respectively held by 10 the capacitors 81 to 86 are extracted at the timing immediately preceding the next update. Specifically, the clock signal CLK1 (number 7) is again output after the clock signal CLK6 (number 6) is output. Therefore, the analog switch 61 connected to the capacitor 81 15 becomes electrically continuous at the output timing of the clock signal CLK6, and the voltage held by the capacitor 81 is extracted on the output terminal side. Thereafter, in a similar manner, the other analog switches 62 to 66 become electrically continuous in a 20 sequential order, and the voltages held by the capacitors 82 to 86 are sequentially extracted.

As described above, the voltage of the input signal at each time point is held in each of the capacitors 81 to 86 by making the switches 51 to 56 25 electrically continuous in a sequential order, and the

held voltage is extracted before being updated by making the switches 61 to 66 electrically continuous, whereby the output timing of the signal can be delayed by the amount of time required from when the switches 51 to 56 are made electrically continuous until when the respectively corresponding switches 61 to 66 are made electrically continuous.

Especially, the analog delaying circuit 252 can be configured by using the switches 51 to 56 and 61 to 66, whose disconnection states can be switched, the capacitors 81 to 86 holding the voltage of a signal, and other additional circuits such as the clock generating circuit 50, etc. This eliminates the need for using a resistor and a capacitor, which have a large device constant. Therefore, the whole of the noise removing circuit 30 including the analog delaying circuit 252 can be easily formed on a semiconductor substrate.

Additionally, since the amount of time required from when the switches 51 to 56 are made electrically continuous until when the respectively corresponding switches 61 to 66 are made electrically continuous becomes the delay time of a signal. Therefore, the delay time can be precisely set according to the generation timing of the clock signal, and the numbers of analog

switches and capacitors. As a result, the timing when the pulse is generated by the one-shot circuit 242, and the delay time implemented by the analog delaying circuit 252 can be made to precisely match, whereby the 5 accuracy of the noise component removal 30 can be improved.

Additionally, the clock signal is generated by the clock generating unit 50, whereby each connection and disconnection timings of the analog switches 51 to 56 10 and 61 to 66 can be controlled. This eliminates the need for a complex control mechanism, and the circuit configurations of the analog delaying circuit 252 and the noise removing circuit 30 can be simplified.

The present invention is not limited to the above 15 described preferred embodiment. Variously modified implementations can be made within the scope of the gist of the present invention. For example, the above described preferred embodiment refers to the noise removing circuit 30 of the FM receiver having the general 20 configuration. However, the present invention can be applied to a noise removing circuit included in a direct conversion receiver, etc. Especially, since a signal is separated into an in-phase component (I component) and a quadrature component (Q component) in the direct 25 conversion receiver, a noise removing circuit must be

used respectively for the separated signals. Accordingly, the present invention is applied to this noise removing circuit, whereby cost reduction can be implemented by significantly simplifying the circuit 5 configuration.

As described above, according to the present invention, the voltage of an input signal is held in each capacitor at each time point by sequentially making the first switches within the analog delaying circuit 10 electrically continuous, and the held voltage is extracted before being updated by making the second switches electrically continuous, whereby the output timing of the signal can be delayed by the amount of time required from when the first switches are made 15 electrically continuous until when the second switches are made electrically continuous. Especially, the analog delaying circuit is configured by using the first and the second switches, whose connection and disconnection states can be switched, and the capacitors 20 that hold the voltage of a signal. This eliminates the need for using a resistor and a capacitor, which have a large device constant, so that the whole of the noise removing circuit including the analog delaying circuit can be easily formed on a semiconductor substrate. 25 Furthermore, the amount of time required from when the

first switches are made electrically continuous until when the second switches are made electrically continuous becomes the delay time of a signal. Therefore, the delay time can be set regardless of variations in 5 device constants. As a result, the timing when the pulse is generated by the pulse generating circuit, and the delay time implemented by the analog delaying circuit can be made to precisely match, whereby the accuracy of noise component removal can be improved.